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Machine Learning-based Renewable Energy Adaptation: Case study Bangladesh

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Abstract: For environmental sustainability and energy security, renewable sources must be incorporated into sustainable energy solutions. Machine learning (ML) techniques are explored in this study to optimize the adoption of renewable energy sources in Bangladesh. Specifically, it proposes a three-phase methodology: (1) forecasting demand for nonrenewable energy, (2) predicting renewable energy availability and costs, and (3) analyzing potential savings and environmental benefits. Utilizing decision trees and random forests, this study presents a comparative analysis of energy demand and cost predictions, contributing to a data-driven framework for energy transition. The results indicate that strategic adoption of renewable energy can mitigate Bangladesh's electricity shortages while reducing dependency on fossil fuels. Machine learning plays a crucial role in energy optimization by accurately forecasting energy demand and availability, allowing for better resource allocation. It helps identify patterns and trends in energy consumption, enabling more efficient integration of renewable sources. By using techniques like decision trees and random forests, machine learning models can optimize energy production and distribution, ultimately leading to more sustainable and cost-effective energy systems.The findings provide policymakers and energy planners with insights to enhance sustainability efforts.

Index Terms: Machine Learning, Conventional Energy, Renewable Energy

1. Introduction

Considering the pressing global need to shift to sustainable energy, there has been a lot of discussion on the costs and benefits of integrating renewable energy into non-traditional systems. Renewable energy technologies—such as solar, wind, biomass, and geothermal—present special opportunities and challenges when incorporated into non-conventional systems. These demand a rigorous cost- and savings estimate as well as meticulous analysis. In this paper, an overview of the significance and difficulties involved in projecting the costs and savings of utilizing and integrating renewable energy into non-traditional systems is given.

Unconventional systems encompass various sectors, including residential, commercial, industrial, and transportation, where renewable energy technologies are applied in non-traditional ways. These systems often involve decentralized energy generation, energy storage solutions, and smart grid applications. Predicting the cost and savings in these contexts is crucial to assessing economic feasibility, financial viability, and return on investment of renewable energy projects. Accurate prediction of costs associated with the implementation of renewable energy involves considering factors such as equipment and installation expenses, grid connection requirements, permitting and regulatory compliance, and ongoing maintenance and operating costs. These factors vary significantly depending on the specific renewable energy technology and the characteristics of the unconventional system. Furthermore, the availability of government incentives, tax credits, and financing options can greatly influence the overall costs and potential savings.

In parallel, predicting potential savings resulting from the adoption of renewable energy in unconventional systems requires an analysis of energy consumption patterns, demand profiles, and energy cost fluctuations. Evaluating the displacement of conventional energy sources, such as fossil fuels, and assessing the long-term energy cost savings is crucial to determining the financial benefits of the integration of renewable energy. In addition, the positive environmental impacts, reduced greenhouse gas emissions, and improved energy resilience associated with the adoption of renewable energy contribute to the overall value proposition of these systems. However, predicting the cost and savings in unconventional systems presents inherent challenges. Factors such as uncertainty in energy markets, volatile fuel prices, technological advancements, and the dynamic nature of energy demand require sophisticated prediction models. Accurate data collection, robust economic modeling techniques, and incorporation of various scenarios and sensitivities become essential for reliable cost and savings predictions. Predicting the cost and savings of using and implementing renewable energy in unconventional systems is vital for making informed decisions, promoting sustainable development, and achieving energy security and resilience. By understanding the economic aspects, financial risks, and potential benefits, stakeholders can evaluate the feasibility of renewable energy projects and drive the adoption of clean energy solutions. Continued research and advancements in predictive models will further enhance the accuracy and reliability of cost and savings predictions, supporting the global transition towards a cleaner and more sustainable energy future.

Numerous studies have emphasized the shift from fossil fuels to renewable energy sources in various geographical areas, with a focus on the advantages for the environment and economic factors. To combat pollution and climate change, nations in southern Asia, such as India and Pakistan, are adopting renewable energy projects even in their armed spheres. However, especially in developing nations like Bangladesh, the installation of these systems requires a careful examination of costs, energy savings, and maintenance requirements. Research articles examine the difficulties and remedies related to the switch to renewable energy, including improving electricity quality, solving intermittent problems, and determining whether integrating renewable energy sources into the current infrastructure is feasible. To assess the effects of renewable energy adoption on electricity markets and systems, mathematical models and analytical tools are developed. Studies show that renewable energy has advantages for the environment, but there are also possible disadvantages and difficulties, like negative effects on the ecosystem and technological constraints. Therefore, to maximize the advantages of adopting renewable energy sources and promote sustainable development, thorough studies that take into account both economic and environmental variables are crucial.

An important detail that these studies did not include was a comparison of several machine learning (ML) models to evaluate renewable energy options in Bangladesh, a country that is experiencing power outages. Such an analysis is essential given the urgent demand for alternative energy sources, especially renewable ones. Moreover, there is a lack of interactive tools that illustrate data on the uptake of renewable energy. These kinds of technologies have the potential to greatly improve comprehension and judgment in this crucial field.

The objective of predicting renewable energy is to develop accurate and reliable models that can forecast the generation and availability of renewable energy from various sources. These predictions aim to provide valuable information on future energy production patterns, enabling effective energy planning, resource allocation, and decision-making. By accurately predicting renewable energy, we can optimize energy management strategies, improve grid stability, minimize energy waste, and facilitate the integration of renewable energy sources into existing power systems. Ultimately, the objective is to maximize the use of renewable energy, reduce dependence on fossil fuels, mitigate environmental impact, and promote sustainable energy practices for a greener and more sustainable future. Solar radiation is a key source of solar energy, so machine learning algorithms have been studied to forecast solar radiation. There are several strategies for forecasting solar radiation.

The world is moving towards renewable energy sources because of the growing demand for energy and the depletion of fossil fuel supplies. Because of its reliance on traditional energy sources, Bangladesh, a developing country with rising energy demands, frequently experiences power outages. Solar, wind, and biomass are examples of renewable energy technologies that provide practical substitutes to guarantee energy security while lessening their negative effects on the environment.

To analyze and forecast energy consumption, evaluate the viability of renewable energy sources, and optimize resource allocation, this study focusses on utilizing machine learning techniques. In contrast to other research, which mostly addresses the viability of adopting renewable energy, this study uses predictive analytics to calculate demand supply gaps and suggest affordable fixes. The goal of the study is to offer an organized method for integrating renewable energy that is specific to Bangladesh's energy environment. The contributions to the paper are as follows:

- The primary contributions of this study include: Development of an ML-driven model to forecast energy demand and assess renewable energy feasibility.
- Comparative analysis of different ML models (decision trees, random forests, etc.) for energy demand prediction.
- A framework for evaluating the economic and environmental benefits of transitioning to renewable energy.

In-depth background information and a thorough literature analysis are included in Section 2, which also includes an overview of key terms found in the body of current research. The technique and system architectural design used in the research are explained in detail in Section 3. Section 4 presents the results of the testing process for each module, along with an analysis of the datasets. Section 5 concludes the study, highlights its shortcomings, and suggests directions for further investigation.

2. Related Works

In this rapidly developing world, every aspect of our lives is taking advantage of science, but unfortunately, it is also contributing to increasing pollution and climate change. As a response, countries around the globe are shifting towards renewable energy sources to mitigate costs and help heal our planet. Southern Asian countries, including India, are embracing renewable energy on a larger scale, even within the military domain. For instance, India is implementing renewable energy initiatives in Jammu and Kashmir to support and uplift war-torn regions [12]. Similarly, in the Peshawar cantonment area, solar energy is being utilized for street lighting to reduce electricity consumption [13]. Therefore, countries like Bangladesh will greatly benefit if those ideas can be implemented properly. However, implementing those systems requires a large amount of cost and maintenance. Therefore, before implementation, developing countries like Bangladesh must analyze how we can implement the idea and how much energy will be saved as well as how much cost will be benefited. As a result, this analysis will play a huge part in implementing renewable energy.

In [1], the problems of conventional energy sources were found out, and the way of subsequently shifting them to green was depicted. This paper will sort out the problems of conventional energy and thereby show a process to shift to green energy. There is a summary of several renewable energy generation technologies that are being developed to support environmentally friendly energy, considering the issues with traditional power generation techniques. An overview of the Indian power situation is provided along with the benefits and drawbacks of conventional generating. Power industry greenhouse gas emissions are confirmed using ANOVA and other statistical tools. India's renewable energy growth has also been analyzed. We also give a brief overview of renewable energy advancements at present and in the future.

In [2] built a mathematical model and created tools for assessing the impact of the penetration of renewable energy in the infrastructural system of the electricity market. The system will be able to implement renewable electricity in an infrastructural system. Both positive and negative effects on the operation of the electricity market and the electric power system may result from the incorporation of renewable energy sources into the infrastructure of the electricity market. The article's goal is to develop a mathematical model and tools for analyzing the effects of the penetration of renewable energy into the market's infrastructure. The investigation's methodology is based on multidimensional time series matrix modeling. The groups of generation sources are formed by grouping power-generating units according to the technologies utilized to produce electricity. The installed producing capacity of groupings of generation sources, the amount of power, and other data measures. Then levels of the multidimensional time series, they choose the electricity they produced and the money they made from selling the electricity they produced. A set of singular square matrices built at each level of the time series make up the integral-matrix model of a multidimensional time series. The column matrix, the row matrix, and their corresponding elements, the direct and inverse numerical values of the embedded time series' sublevels, are multiplied to create each square matrix. Individual and integral indices of groups of sources of generation were produced by performing algebraic operations on the square matrix's elements. to evaluate shifts in the indicators' heterogeneity, monopolization, and concentration. The three mean value methods—harmonic mean, arithmetic mean, and root mean square values—are used to calculate the indices. These metrics are suggested for use in a quantitative analysis of the penetration of renewable energy into the infrastructure supporting the electricity market. Future analyses of the viability of the principle of equivalence of generation sources in the infrastructure system of the energy market will make use of this methodological approach.

Whereas article [4] found out the feasibility of using Renewable energy in the future for the United States. The technology will be more than sufficient to supply 80 percent of all U.S. power generation. The main findings of the RE Futures Study are highlighted in this report. This article goes to great lengths about renewable energy sources in the US.

The paper's focus is technical difficulties with the functionality of the American electrical grid and offers preliminary responses to crucial queries regarding the national integration of highly invasive renewable electricity technologies. The findings show that it is feasible for the United States to have an electrical system in the future that is primarily powered by renewable resources and that more research into this clean generation pathway is necessary. The analysis's main finding is that using currently commercially available technology for renewable electricity generation in conjunction with a more flexible electric grid will be more than sufficient to supply 80 percent of all U.S. power generation in 2050 and satisfy hourly electricity demand across the country.

Finally, in [5], the application, difficulties, and prospects of renewable energy sources were discussed. In this paper, the way of implementing different renewable sources like solar, wind, tidal, hydro, geothermal, and biomass is described. According to population growth, energy demand has grown rapidly. Besides these, economic and technological improvements demanded energy utilization. But the world's treasured energy is limited. Again, more use of conventional energy produces more greenhouse gases. So, to save our planet, we should not be biased on conventional energy. This paper has established an idea about different applications of renewable energy, its difficulties, and its solutions.

The use of renewable energy is evident in our everyday lives. Additionally, this area is the subject of extensive research. As a result, it is pretty like us all. But many times, it has happened that we did not first investigate how much we could save in terms of both money and energy. Yes, it is undeniably true that using renewable energy allows us to use less energy while also reducing environmental pollution, but let's refrain from estimating how much money we can save. That ought to make up a significant portion of the study. Using machine learning, we can create a system that focuses on this area.

The integration of renewable energy sources and their effects on energy security have been the subject of previous research. Few, meanwhile, have really examined how ML might be used in Bangladesh to forecast demand and maximize the distribution of renewable energy. Although research in [1–3] shows how well machine learning approaches work for energy forecasting, there is still a dearth of comparative analysis that considers the nation's particular economic and meteorological circumstances.

By comparing the effectiveness of many machine learning models in forecasting energy demand and renewable energy potential, this study expands on earlier research. Additionally, it bridges the gap between theoretical research and realworld implementation by introducing an interactive tool to visualise patterns in the uptake of renewable energy.

2.1. Research Gap

A crucial component has been absent from the research done thus far: a comparison of several machine learning (ML) models for evaluating renewable energy options in Bangladesh, a country beset by power blackouts. Such an analysis is essential given the urgent demand for alternative energy sources, especially renewable ones. Furthermore, there is a conspicuous lack of interactive tools that can visualize data pertaining to the uptake of renewable energy. These technologies have the potential to greatly improve comprehension and judgment in this important area.

A thorough examination of several machine learning algorithms could reveal the advantages and disadvantages of each model in terms of forecasting Bangladesh's adoption of renewable energy. Researchers can identify which model provides the most dependable predictions by contrasting the performance metrics—such as accuracy, precision, and recall—of several models, including decision trees, random forests, support vector machines, and neural networks. Furthermore, it is imperative to assess the computational efficiency and scalability of these models, particularly in the context of a resource-constrained setting such as Bangladesh.

Moreover, a major gap in the state of current research is the lack of interactive tools that can visualize data on renewable energy. Better decision-making might be facilitated by creating user-friendly interfaces that let stakeholders interactively examine facts about the uptake of renewable energy. Features like time series analysis for energy demand forecasting, geographic information systems (GIS) for mapping renewable energy potential, and scenario modeling for evaluating the effects of policy interventions might all be included in these tools.

To sum up, a thorough examination of several machine learning models for assessing renewable energy alternatives in Bangladesh and the creation of interactive visualization tools have the potential to greatly improve research and policy development in the renewable energy field. These programs could help alleviate the nation's energy problems and promote sustainable development.

3. Methodology

3.1. Terminologies

In this section, on we will discuss energy-related terminology.

Natural Resources Any material or substance that can be found in nature that is valuable to humans is considered a natural resource. Minerals, forests, air, water, and fossil fuels are a few examples. These resources can be classified as non-renewable (coal and petroleum) or renewable (solar energy and wood). The development of the economy and the welfare of people depend heavily on natural resources. For future generations to be able to access them, sustainable management is essential.

Green House Effect A natural phenomenon known as the "greenhouse effect" occurs when certain gases in the Earth's atmosphere retain solar heat. These gases, which include water vapor, carbon dioxide, and methane, function similarly to a greenhouse's glass by letting light in while keeping some heat from escaping back into space. Because of the trapped heat, life is possible on Earth since the surface is kept warmer than it would be otherwise. Global warming is a result of human activity increasing the quantities of these gases, particularly through the combustion of fossil fuels and deforestation. The ensuing climatic shifts may lead to severe weather, increasing ocean levels, and ecological effects.

Cost Effectiveness The efficiency of various interventions or actions in reaching a particular outcome in relation to their costs is measured by their cost-effectiveness. It contrasts two or more courses of action's relative costs and results. This method aids in figuring out which choice offers the best outcomes at the lowest cost. It is extensively utilized in domains like public policy, business, and healthcare. The objective is to reduce costs and maximize the intended result.

Solar Radiation The energy that the Sun emits as electromagnetic waves, such as visible light, ultraviolet light, and infrared radiation, is known as solar radiation. This energy powers the planet's weather and climate systems and facilitates photosynthesis in plants, which is essential to life as we know it. Solar panels are used to capture solar radiation and turn it into electrical power. The location, season, and air conditioning all affect how intense the sun's radiation is. Instruments like radiometers and pyranometers are used to measure it.

3.2. Proposed Methodology

For a better understanding and interpretation of the work, we have divided the proposed methodology into three modules. These are given below:

- Phase 1: Forecasting Demand prediction of present non-renewable energy
- Phase 2:Prediction of the demand of renewable energy
- Phase 3: A comprehensive assessment of the potential savings achievable by transitioning from non-renewable to renewable energy sources.

Phase 1: Forecasting Demand prediction of present non-renewable energy by leveraging historical data encompassing previous months or years of energy demand, cost, and usage, this project endeavors to forecast vital indicators for the upcoming days. It is anticipated that such forecasts will reveal substantial deficiencies between projected demand and available supply, highlighting the urgency for sustainable energy solutions. In this phase, we are putting the present system into action, taking different data to train the model, and after that, we will evaluate the model by giving some external input that it can predict properly or not.

Phase 2:Prediction of the demand of renewable energy Recognizing the imperative to meet the present demand, this project will focus on forecasting the costs associated with harnessing renewable energy sources that can effectively replace non-renewable counterparts. Extensive research will be conducted to ascertain the characteristics, availability, and costs of various renewable energy options, including solar and wind. Accurate forecasting methodologies will be employed to estimate future demand and costs, accounting for factors such as installation expenses, ongoing maintenance, and potential government incentives or subsidies. We will take weather data and historical data and then we will be sure of how much renewable energy we can save.

Phase 3: A comprehensive assessment of the potential savings achievable by transitioning from non-renewable to renewable energy sources. Within this critical phase, a comprehensive assessment of the potential savings achievable by transitioning from non-renewable to renewable energy sources will be conducted. This evaluation will encompass the projected costs and demand forecasts derived from the previous stages. Moreover, it will encompass an analysis of the environmental benefits offered by renewable energy, such as reduced greenhouse gas emissions and improved air quality. Evaluating potential challenges, such as infrastructure requirements and technological limitations, will provide a balanced perspective. Armed with this analysis, informed decisions can be made, and recommendations can be presented, emphasizing the substantial cost savings and environmental advantages associated with adopting renewable energy sources.

3.3. Machine Learning Models

We have chosen 4 different machine learning algorithms, which is frequently used in this domain and have significance improvement in this domain.

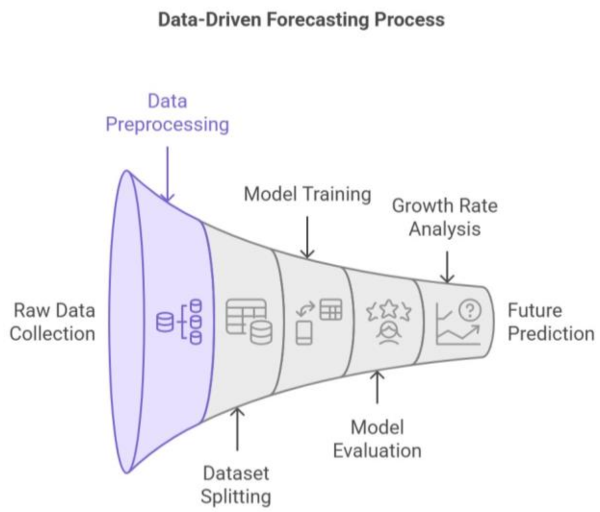

Fig. 1. Flow Chart of Phase 1

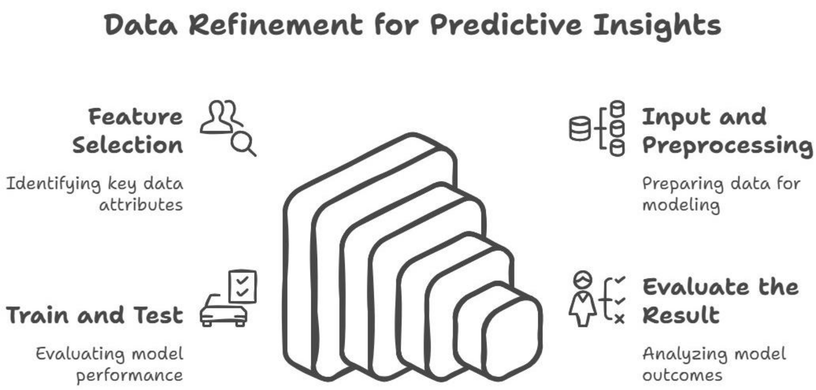

Fig. 2. Flow Chart of Phase 2

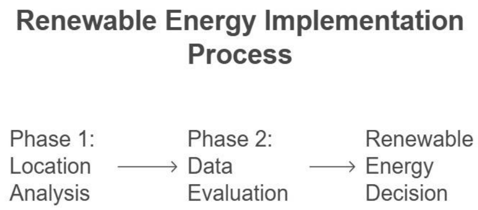

Fig. 3. Flow Chart of Phase 3

Decision Tree: The partition data is questioned repeatedly to create a decision tree. By increasing the predictiveness at each stage of partitioning, the decision tree approach seeks to ensure that the model is continuously updated with dataset information. Despite being a supervised supervised learning method, its primary application is in classification as opposed to regression. In summary, the model utilizes a conditional statement to compare significant attributes as it iteratively navigates the decision tree for a given instance. The more significant traits are nearer the root as they descend to the left or right child branch of the tree, depending on the outcome. This machine learning algorithm's benefit is that it can be applied to both continuous dependent and categorical

Random Forest: Leo Breiman and Adele Cutler are the trademark holders of the widely used machine learning technique known as ”random forest,” which aggregates the output of several decision trees to produce a single conclusion. Its versatility and ease of use, combined with its ability to handle both regression and classification problems, have driven its popularity. The three primary hyperparameters of random forest algorithms must be set prior to training. These consist of the size of the nodes, the count of trees, and the quantity of characteristics sampled. Regression and classification issues can then be resolved using the random forest classifier. Each decision tree in the ensemble of decision trees used in the random forest technique is made up of a bootstrap sample, which is a sample of data taken from a training set with replacement.

Linear Regression: Based on continuous features, Python Machine Learning maintains an observation and predicts a result. By fitting the best line, a relationship is established between dependent and independent variables. The regression line is the line that provides the best relationship between dependent and independent variables. Whenever it is run on a single variable or feature, we call it simple linear regression, and when it is run on multiple variables, we call it multiple linear regression. Using continuous variables, this is often used to estimate the cost of houses, sales, or calls.

XgBoost: XGBoost is a powerful machine-learning algorithm that helps you understand your data. Gradient-boosting decision trees are implemented. Researchers and data scientists worldwide use it to optimize machine-learning models. Gradient boosting is widely implemented in XGBoost. It offers regularization, which allows you to control overfitting by introducing L1/L2 penalties on the weights and biases of each tree. This feature is not available in many other implementations of gradient boosting. Another feature of XGBoost is its ability to handle sparse data sets using the weighted quantile sketch algorithm. This algorithm allows us to deal with non-zero entries in the feature matrix while retaining the same computational complexity as other algorithms like stochastic gradient descent.

3.4. Implementation:

There are two parts of our implementation. Machine Learning Algorithm and Panel Dashboard. redCode is aviable in this link https://drive.google.com/drive/folders/1gMA06Eu$_b DljcjjlrP71W - soaEsGuIie?usp = drive_l ink.$

3.4.1 Machine Learning Algorithm:

The implementation of machine learning algorithms was carried out using the sklearn library. The training of these models took place on Google Collaboratory using Python. In the Algorithm , we have outlined the specific steps for conducting the experiment. [!h]

Algorithm 1

- Input
- Train Data
- Test Data
- Output
- Performance Metric Scores while (stopping condition is not met) do
- Initialize the ML models M1, M2, ..., Mk
- Fit the model to the training data
- Predict the target for the test features using the trained model
- Evaluate performance metric scores using predicted target and test targets end while

Return Performance metric scores The graph of feature prediction in the Weather Dataset is shown in Figure 4: The prediction of the feature is shown in Figure 5:

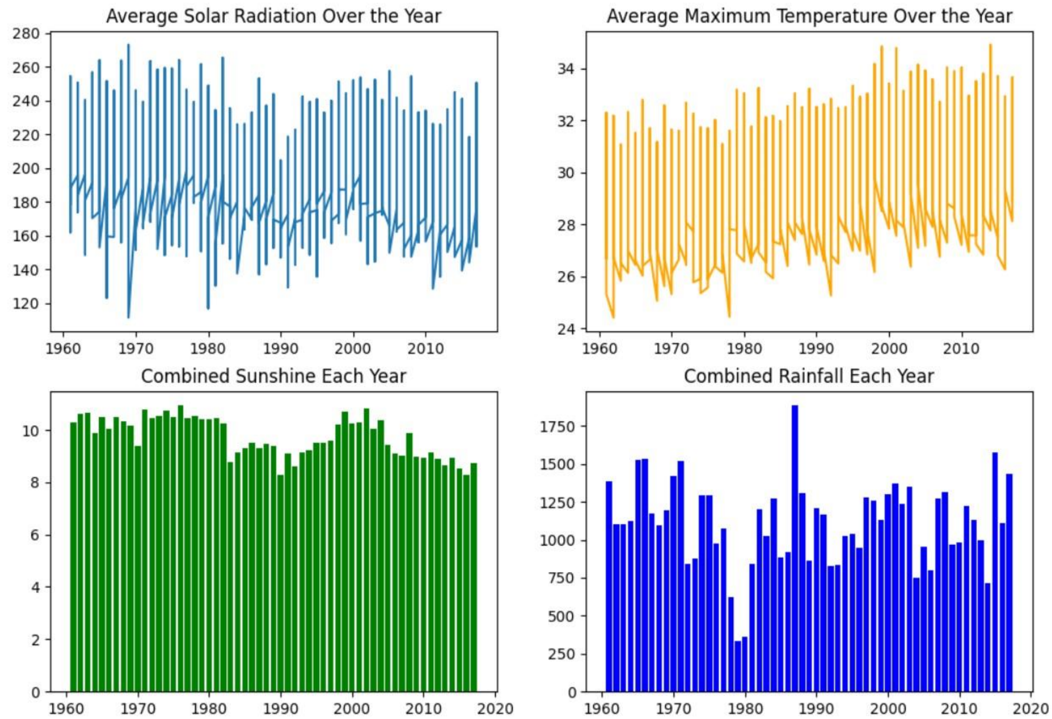

Fig. 4. Analysis of Weather Data

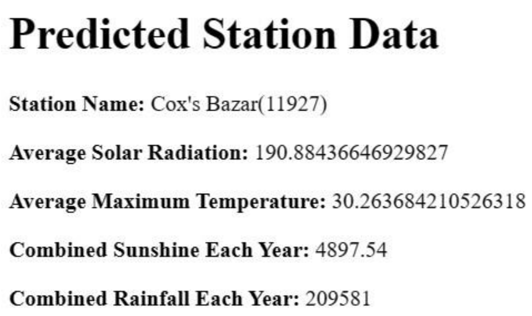

Fig. 5. Prediction of Weather Data

Panel Dashboard: We have used Flask for our Panel Dashboard. Flask is a micro framework written in Python, making it a popular choice for building web applications. Unlike some larger frameworks, Flask offers a minimalist approach, providing a core set of functionalities while allowing developers to choose the additional tools and libraries they need for their project. Because of its clear and straightforward syntax, Flask is a great tool for learning web programming. This is especially useful for novices who want to understand the basics. Because of its simple configuration, web applications may be quickly created and tested by developers through rapid prototyping. Additionally, because Flask handles a variety of development demands efficiently, it’s a great choice for building small to medium-sized online apps, from straightforward websites and blogs to complex APIs.

In the dashboard, we can select a specific year, month, station code, and specific model to see the electricity demand, generation, and deficiency. The calculation of Demand Figure-6 Figure-7.

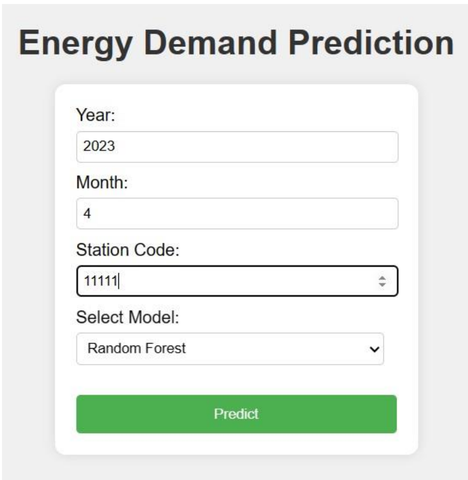

Fig. 6. Input given for Demand Prediction

Using Bar chart, this deficiency is also shown with the help of demand and generation Graph. The per hour and per day generation are also shown in Fig. 10.

4. Experiment Setup

4.1. Data Collection and Analysis

The process of gathering, quantifying, and evaluating precise research insights using accepted, verified methods is known as data collection. Based on the evidence gathered, a researcher might assess their hypothesis. Regardless of the.

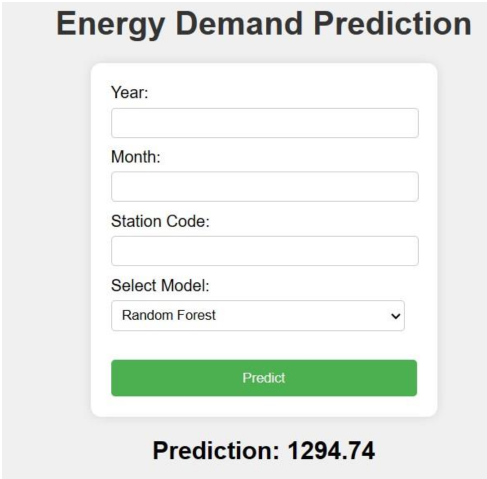

Fig. 7. Predicted Demand

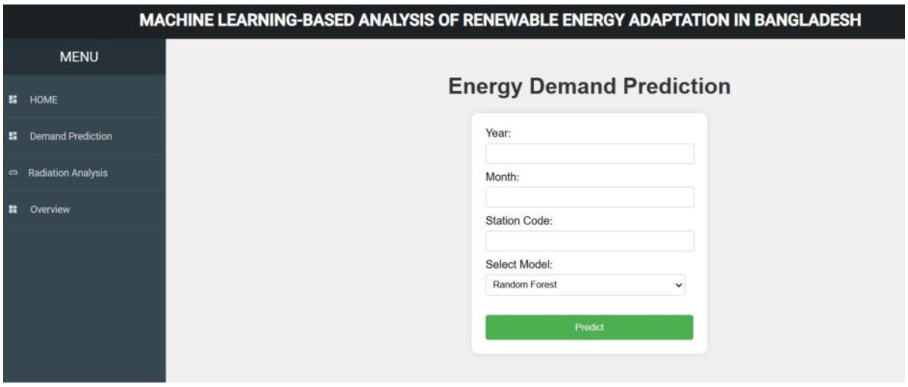

Fig. 8. Bar charts for Demand vs Generation

Study subject, gathering data is typically the first and most crucial stage in the process. Depending on the information needed, different disciplines of research use different data collection strategies.

The dataset consists of meteorological data from the Bangladesh Agricultural Research Council (BARC) and energy usage statistics from the Dhaka Electric Supply Company (DESCO). Mean Absolute Error (MAE), Mean Squared Error (MSE), and R-squared (R^2) scores are important evaluation measures.

4.2. Data Repository

Bangladesh Agricultural Resources Council (BARC) Bangladesh Agricultural Research Council (BARC) is the body in charge of the National Agricultural Research System and is in Farmgate, Dhaka, Bangladesh. From BARC the dataset of Solar Radiation is collected. There the monthly radiation of different districts is depicted.

4.3. Dataset

Two datasets serve as the foundation for our experiment: Bangladesh's electricity demand and meteorological data. The Dhaka Electric Supply Company (DESCO) provided the electricity dataset. We created columns labeled "Year, Month,

Station, and Demand by focusing just on the month and year to streamline the data. The Bangladesh Agricultural Research Council (BARC) provided the weather dataset. We choose to use the columns Year, Month, Station, and Radiation as the objective variable because we are concentrating on implementing renewable energy. Three columns are shared by both datasets. Below is a thorough explanation of the aspects of the dataset:

Table 1. Dataset Details

Column Name	Description
Year	Previous few years
Month	Shown in numerals
Demand	Electricity demanded in month, measured in megawatts
Radiation	Solar Radiation per month are given

4.4. Evaluation metrics

We will follow a total of four performance matrices to evaluate our result. A description of those four performance matrices is given below:

Mean Absolute Error (MAE): the average of the absolute differences between predicted and actual values.

$$\text{MAE} = \frac{1}{\text{n}}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

Interpretation: MAE gives the average magnitude of errors in the predicted values.

Mean Squared Error (MSE):The average of the squared differences between the predicted and actual values.

$$\text{MAE} = \frac{1}{\text{n}}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

Interpretation: MSE penalizes larger errors more than smaller ones due to squaring.

Root Mean Squared Error (RMSE):

The square root of the MSE.

$$\text{RMSE} = \frac{1}{\text{n}}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \ \text{MSE}$$

Interpretation: RMSE is in the same unit as the target variable and provides a more interpretable measure of error.

R-squared (R^2): Definition: the proportion of the variance in the dependent variable that is predictable from the independent variables. Formula:

$$\text{R}^2 = 1 - \frac{SS_{\text{res}}}{SS_{\text{tot}}}$$

Interpretation: R^2 ranges from 0 to 1; higher values indicate better model fit.

4.5. Experiment Result

In terms of demand, we see that Dhaka station has the highest demand. The gradually Chittagong, Barishal, Rajshahi, Rongpur, Sylhet But in case of the radiation dataset, Chittagong is at the top. Gradually Rajshahi, Dhaka, Khulna, Barishal, Comilla are shown. If we compare the two analysis, then we can see that Dhaka, Chittagong and Rajshahi are the top three stations. So, we can plan for any of this station. The figs. 9 and fig-10 depict an analysis of demand and an analysis of radiation, respectively.

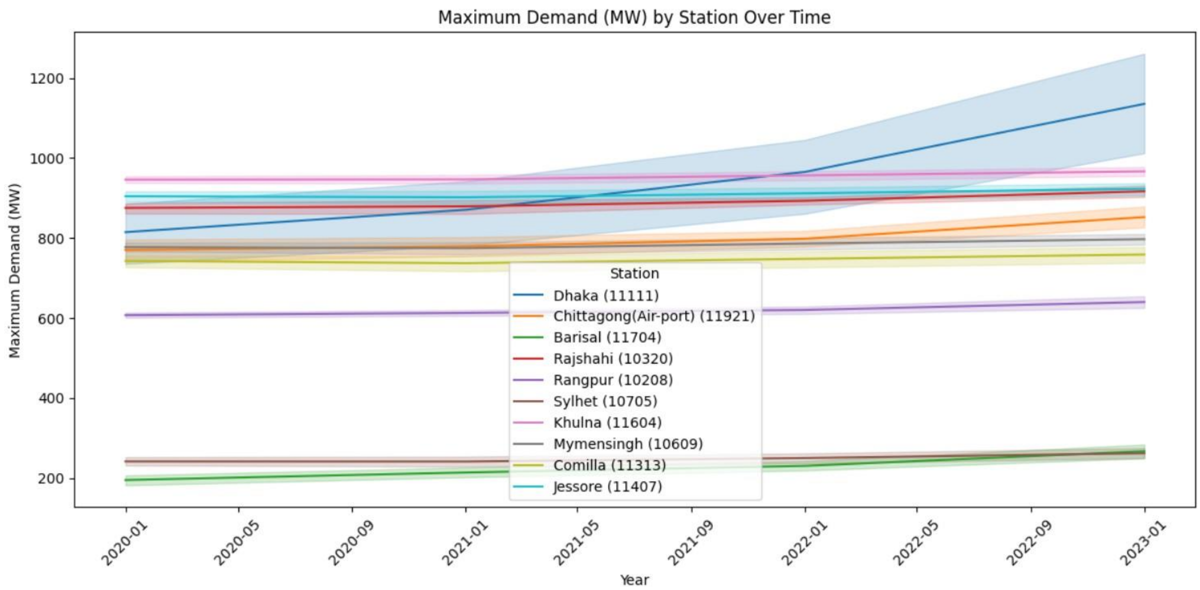

Fig. 9. Monthly Demand Analysis

Station	Solar Radiation
Cox Bazar	190.8843665
Kutubdia	187.6904787
Teknaf	187.375595
Chittagong	185.1740838
Rajshahi	181.5026068
Dhaka	181.1118811
Khulna	181.0617035
Sondip	180.880195
Bagura	180.7744444
Barishal	180.0626307
Shatkhira	180.0227614
Comilla	179.959497

Fig. 10. Monthly Radiation Analysis

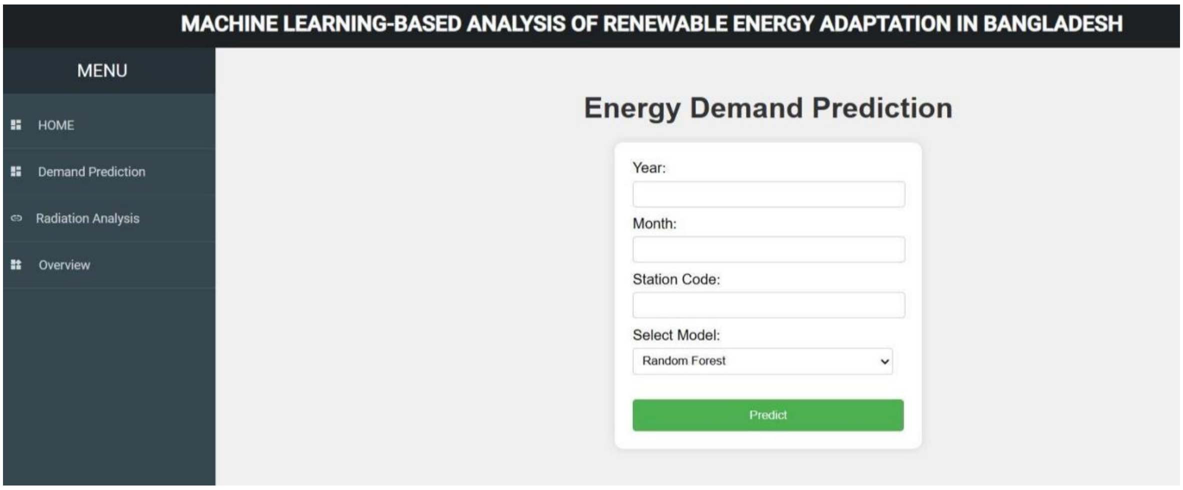

Fig. 11. Monthly Demand Analysis

5. Conclusion

This paper compares four different machine learning models to find the best method for comparing renewable and traditional energy sources. The study's main objective was to perform a thorough comparison analysis between the radiation of solar energy and the demand for conventional energy. Renewable energy alternatives could make up any shortfall in energy supply after determining how much of it can be supplied by traditional sources. This strategy tackles the region's electricity shortage in addition to reducing the extra strain on traditional electricity.

Additionally, incorporating renewable energy sources could result in lower production costs for power. One way to lower the overall cost of generating electricity is to take advantage of solar energy. The economy of a developing country like Bangladesh is significantly impacted by this decrease in production costs. There is a chance for significant economic gains if the use of conventional energy declines and renewable energy becomes a larger part of the energy mix.

Adoption of renewable energy technologies can result in less reliance on imported fuels, investment opportunities, and the creation of jobs. Furthermore, nations like Bangladesh can improve energy security and shock resistance by diversifying their energy portfolio. Overall, this study's findings highlight how crucial it is to use machine learning models to optimize the distribution of energy resources and advance sustainable economic growth by integrating renewable energy sources.

Discussion and Analysis Results show that ML models can correctly forecast trends in energy demand, with Random Forest outperforming Decision Trees in this regard. The necessity of choosing models according to dataset properties and prediction needs is brought to light by a comparative analysis of machine learning techniques. Furthermore, according to the economic analysis, switching to renewable energy sources can eventually save a lot of money and lessen dependency on imported fossil fuels. A possible decrease in greenhouse gas emissions is revealed by environmental analysis, which is consistent with Bangladesh's sustainability objectives.

6. Conclusion

An ML-driven method for predicting energy consumption and maximizing the integration of renewable energy sources in Bangladesh is presented in this paper. The findings demonstrate that adopting renewable energy is feasible and offers substantial advantages in terms of cost savings and environmental sustainability. Future research will concentrate on growing the dataset, adding more machine learning models, and creating an interactive dashboard for energy analysis in real time.

Future Work

Bangladesh is in an area with consistently high sun radiation. To choose the ideal position, we will examine several locations that are close together in the future. In addition to solar radiation, other factors such as topography and elevation, flora and natural resources, wind direction, etc., are also important in locating hotspots for renewable energy. We'll factor those in for a more precise figure. Collaboration with government organizations, IT firms, and industry leaders to gain access to actual data, knowledge, and resources.

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